than weaken the general thesis that bacteria represent a very ancient form of life, for the denitrifying bacteria are generally conceded to be higher in the scale of bacterial life than either the nitrogen fixers or the nitrifiers. If organisms related to the higher denitrifiers existed in the Algonkian, is it not reasonable to assume that simpler forms existed earlier in geologic time? In other words, the hypothetical point as to whether the Algonkian bacteria represent forms related to the nitrifiers or the denitrifiers is immaterial to the conclusion regarding the great antiquity of bacteria.

As to the matter of "popular science" in general the popularizer always runs into danger as soon as he leaves his own special field of research. No one is more conscious of such pitfalls than myself; it is difficult enough to avoid pitfalls in one's own field without venturing into others. At the same time I feel very strongly that little or no progress will be made in the principles of biology (as distinguished from discoveries in special fields of research) unless biologists have the courage to venture occasionally into the fields of physics, chemistry, physiology and zoology in order to look at life from a broader and more distant point of view. Such an attempt I have made in the Hale Lectures which Dr. Breed cites and which now appear in a somewhat more carefully considered form in "The Origin and Evolution of Life." On every topic I have sought and found the cooperation and criticism of other workers—in physics of Pupin, in chemistry of Gies and Clarke, in zoology of Wilson, in astronomy of Hale and Russell, in botany of Goodspeed and Howe, and many others. Although every effort has been made to guard against errors, it may be that others have slipped in, but I take it for granted that specialists will not mistake a popular work for a work of reference nor imagine that I presume to speak with the authority of a specialist in any field but my own.

Henry Fairfield Osborn

THE TEACHING OF OPTICS

The recent discussion in the columns of Science as to the best method to be followed in presenting the fundamental laws and concepts of mechanics to the student has been followed with much interest by teachers of physics. To the writer it seems equally important that attention be directed to another branch of physics, and the question raised as to whether there should not be a radical change in our methods of introducing the student to the subject of optics.

It is generally conceded by those qualified to speak with authority that the establishment of the electromagnetic theory of light represents one of the greatest achievements of modern science. Yet in spite of the far-reaching importance of this principle, the average student who has completed his college course in general physics, or even in many cases more advanced special courses, is entirely unfamiliar with the meaning or the significance of the electromagnetic theory. This need occasion no surprise, however, in view of the methods commonly employed at present in teaching the subject of optics. For certainly a text-book which either does not mention the electromagnetic theory of light or relegates it to a footnote or inconspicuous paragraph is hardly calculated to inspire the student with any great respect for that theory. This criticism applies, not to our text-books alone, but with equal force to the ordinary lecture course.

In order to investigate the justice of this claim that one of the most important principles of modern physics is almost entirely ignored in our present system of teaching and is seldom accorded the attention its importance demands, the writer recently made a careful examination of ten representative text-books of physics, all of them published within the past decade and including practically all, so far as known to the writer, which are very extensively used in our American colleges and universities at the present time. As a result of this examination it was found that in three of these text-books no reference whatever is made to the electromagnetic theory; three other authors content themselves with a bare mention of the theory;

in four of the books an attempt is made to state a few of the more important consequences of the theory, but in practically every case this discussion is limited to one or two paragraphs, either at the very end of the book or at the end of the subject of electricity. (It is a striking fact that nearly all of these authors who deem the electromagnetic theory of light worthy of any comment at all, discuss it, not where we would naturally look for it—under the head of "Light"—but under "Electricity," and then proceed calmly to ignore it when "Light" is taken up!) In only one of the text-books examined is there any attempt at the outset to make clear to the student what light really is or to bring out the fact that there is an intimate connection between optical and electrical phenomena. In not one of the books is the electromagnetic theory made the basis of the treatment of light.

In most of our text-books there is a chapter entitled "The Nature of Light" or "Theories of Light," in which pains are taken to relate the triumph of the wave theory of light over the corpuscular theory, but in practically every case the author stops short before coming to the crux of the whole matter; there is no suggestion as to what kind of waves light waves are. This is a question which is sure to occur to the student, if he be of a normally inquiring turn of mind, but his perplexity is left unanswered. Certainly no teacher would think of omitting from a discussion of sound waves an explanation of what kind of waves sound waves are; yet this is the common procedure when light waves are discussed.

Only two ideas suggest themselves as reasons for the common neglect of so important a principle; either the electromagnetic theory is thought to be not yet sufficiently well established to find a place in our text-books, or it is thought to be too difficult for the average student to grasp. As to the former, few will question the fact that the theory has been abundantly verified from every point of view and has been firmly established long enough to justify its occupying a prominent place in our text-books and lectures.

The opinion is widely prevalent, however, that the electromagnetic theory presents difficulties so great as to be insuperable for the average college undergraduate. While it may be admitted that the mathematical development of Maxwell's equations and their application to the various cases of reflection, refraction, and dispersion are decidedly beyond the grasp of the average sophomore, yet it is surely possible to present the essentials of the theory in non-mathematical form, and to discuss its more important consequences, as was attempted by the writer in a recent number of *The Scientific Monthly*. As to the vagueness which many feel to be inherent in any attempt to picture a light wave on the electromagnetic theory, we may remark that our conception of an electromagnetic wave is precisely as definite as our ideas of an electric or magnetic field.

It is true that many of the phenomena of light can be given a very simple explanation in terms of the so-called "elastic solid theory," but whatever the advantages offered by the conventional mode of presentation, they are more than counterbalanced by the simple fact that in the light of our present knowledge it is not true to the facts. Certainly our aim in teaching should be to inculcate a knowledge of reality, not of convenient fictions with regard to the processes of nature. In more than one of the text-books under consideration frequent reference is made to the "vibrating ether particle" which it is assumed serves to transmit a light wave. It would be interesting to know just what sort of a thing an "ether particle" is conceived to be, but quite apart from the absurdity involved in the use of such a term, there can be no doubt that the conception which the expression "vibrating ether particle" tends to fix in the mind of the student is erroneous and misleading. And so with certain other of the stock phrases we have become accustomed to use in dealing with the phenomena of light.

The ideal course in optics, in the opinion of the writer, should be based from first to last upon the electromagnetic theory. A

chapter on electromagnetic waves under the head of "Electricity," in which the nature and chief properties of these waves and their application in wireless telegraphy are briefly discussed, paves the way for a more thoroughgoing discussion of these waves under the head of "Light." From the beginning of his study of light to the end the student should never be allowed to lose sight of the fact that light is essentially an electromagnetic phenomenon; each branch of the subject should be developed on the basis of this theory; and the intimate relationship between the optical properties of a body and its electrical properties should be constantly stressed.

There is perhaps no other branch of science in which the disparity between the point of view of the investigator and that of the elementary student is quite so great as in optics. The modern worker in this field thinks of the phenomena of light in terms of electromagnetic waves and the behavior of electrons under the influence of these waves; to the student, on the other hand, the ideas which form the working basis of the investigator in his researches are meaningless, because he has no knowledge of the theory upon which these depend or of the experimental facts which underlie them. It must be admitted that in all essentials the subject of light is taught to-day very much as it was taught fifty years ago; exactly as we might expect it to be taught if Maxwell had never lived and if the theory which we owe to him had never been suggested. It is to be sincerely hoped that the near future may witness a radical change in this respect, and that those principles which serve as the groundwork of the modern physicist and which guide him in his researches may be correspondingly stressed in our attempts to present the essential facts of optics to the student.

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TRANS-PACIFIC AGRICULTURE

Whatever the merits of the particular case, the coincidence between the design called House of Tcuhu in Arizona and the Minoan Labyrinth in Crete, described in Science for June 29, page 677, is of interest as an illustration of a large class of facts in need of the more general scientific consideration that Professor Colton bespeaks. The statement, "There are three possible explanations of the coincidence," needs to be extended. American origin and prehistoric transportation to the old world is a fourth possibility as worthy of consideration as pre-Columbian transfer from the old world to America, introduction with the Spanish conquest, or independent origins in the two hemispheres.

Several cultivated plants of American origin appear to have been carried across the Pacific in prehistoric times, such as the coconut palm, the sweet potato, the bottle gourd, the yam bean, and the Upland species of cotton. The same name for sweet potato, *cumara* or *kumara,* is used by the Indians of the Urubamba valley of southern Peru and by the Polynesians, and other plant names are similar. Moreover, since the migrations of the prehistoric Polynesians extended across the Pacific and Indian Oceans, from Hawaii and Easter Island to New Zealand and Madagascar, it is not unreasonable to look for traces of communication with ancient America in the early civilizations of Asia, Africa or the Mediterannean region.

Agriculture is the primary, fundamental art of civilization, and the evidence of the cultivated plants is the most concrete of any that bears upon the question of prehistoric communication between the more civilized peoples of the two hemispheres. No such significance can be ascribed to the contacts or migrations of non-agricultural people across Bering Strait or the Aleutian Islands. For ethnologists, it may be easy to assume that agriculture had separate beginnings in the old world and the new, but botanists are unable to believe that the same genera and species of cultivated plants originated independently in the two hemispheres, or that they were carried across the Pacific without human assistance.

Peru undoubtedly was the chief center of